

Characteristics of 100+ Kepler Asteroseismic Targets from Ground-Based Observations*

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We present results of our 5-years-long program of ground-based spectroscopic and photometric observations of individual Kepler asteroseismic targets and the open clusters NGC 6866 and NGC 6811 from the Kepler field of view. We determined the effective temperature, surface gravity, metallicity, the projected rotational velocity and the radial velocity of 119 Kepler asteroseismic targets for which we acquired high-resolution spectra. For many of these stars the derived atmospheric parameters agree with T_{eff} , $\log g$, and $[\text{Fe}/\text{H}]$ from the Kepler Input Catalog (KIC) to within their error bars. Only for stars hotter than 7000 K we notice significant differences between the effective temperature derived from spectroscopy and T_{eff} given in the KIC. For 19 stars which we observed photoelectrically, we measured the interstellar reddening and we found it to be negligible. Finally, our discovery of the δ Sct and γ Dor pulsating stars in the open cluster NGC 6866 allowed us to discuss the frequency of the occurrence of γ Dor stars in the open clusters of different age and metallicity and show that there are no correlations between these parameters.

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1 Introduction

Our program of ground-based spectroscopic and photometric observations of stars selected for the asteroseismic targets for the Kepler space telescope by the Kepler Asteroseismic Science Consortium KASC¹ was started in 2005 at the Osservatorio Astrofisico di Catania, OACt, (the *M.G. Fracastoro* station, Mt. Etna, Italy) and is continued since then. Apart from the OACt, we perform spectroscopic and photometric observations of Kepler asteroseismic targets at the F. L. Whipple Observatory, FLWO, (Mount Hopkins, Arizona, USA), and the Astrophysical Observatory of the University of Wrocław in Białków (Poland).

At the OACt, we use a 91-cm telescope, at FLWO, a 1.5-m telescope, and at the Białków Observatory, a 60-cm telescope. We make use also of the archival data collected at the 1.5-m telescope at the Oak Ridge Observatory, ORO, (Harvard, Massachusetts, USA) and at the Multiple Mirror Telescope, MMT, before it was converted to the monolithic 6.5-m mirror.

* The data used in this paper have been obtained at the Wrocław University Observatory in Białków, the Osservatorio Astrofisico di Catania, the F. L. Whipple Observatory, Mount Hopkins, Arizona, the Oak Ridge Observatory, Harvard, Massachusetts, and the MMT.

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¹ Kepler Asteroseismic Science Consortium (KASC) is a group of collaborating scientists and/or institutions established to accomplish the activities of the Kepler Asteroseismic Investigation (KAI), represented by Ronald Gilliland (see <http://astro.phys.au.dk/KASC>).

Using the spectroscopic data acquired at OACt, FLWO, ORO, and MMT, we aim at the determination of the atmospheric parameters of the program stars, i.e., the effective temperature, T_{eff} , surface gravity, $\log g$, and metallicity, $[\text{Fe}/\text{H}]$, and measuring the projected rotational velocity, $v \sin i$, and the radial velocity, v_r , of the stars.

At the Białków Observatory, we perform photometric time-series observations of the open clusters NGC 6866 and NGC 6811 in the Kepler field of view, aiming at the discovery of new pulsating stars, and the determination of the degree of the modes of their pulsations.

Both sites, the Białków Observatory and the OACt, took part in the international multi-site photometric campaign on NGC 6866 launched in 2009, and will take part in a similar campaign on NGC 6811 which will be launched in 2010 (for the details, see Uytterhoeven et al. 2010b.)

2 Radial velocity and the projected rotational velocity

When analyzing the spectrograms with the aim of deriving the atmospheric parameters, we measured the projected rotational velocity of the program stars and their radial velocity. As expected, we found the F, G, and K type stars to be slow rotators having $v \sin i$ typically below 5 km s^{-1} . The early-type stars discussed by Catanzaro et al. (2010) rotate significantly faster and although several of them have $v \sin i < 10 \text{ km s}^{-1}$, this low projected rotational velocity

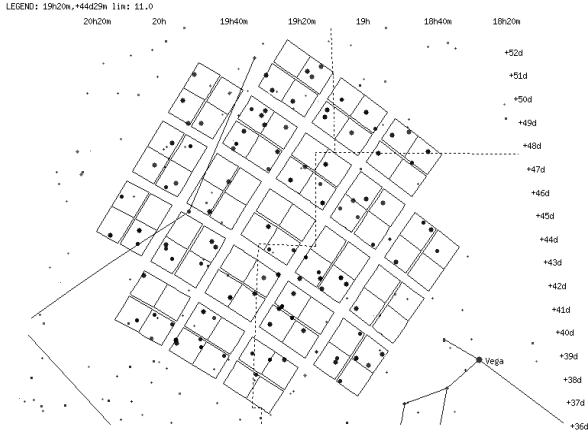


Fig. 1 The Kepler asteroseismic targets observed at the Osservatorio Astrofisico di Catania, the F. L. Whipple Observatory, and the Oak Ridge Observatory. Indicated are the borders of the 42 Kepler CCDs and the borders of the constellations.

may be due to the orientation of the axis of the rotation of the star in the sky.

From the analysis of the radial velocities of the program stars, we discovered six single-lined, SB1, and four double-lined, SB2, spectroscopic binaries (see Molenda-Żakowicz et al. 2007, 2010; Molenda-Żakowicz, Frasca & Latham 2008; Catanzaro et al. 2010; Frasca et al. 2010). For two of the new SB1 systems and one new SB2 star we calculated the systems' mass functions and the orbital solutions, respectively. More spectroscopic and photometric observations are needed to derive the mass functions and orbital solutions for the remaining stars, and to check which of these systems are eclipsing.

In Table 1, we give the number of the spectrograms acquired for each program star at the OACt, FLWO, ORO and MMT.

3 Atmospheric parameters

We measured the effective temperature, T_{eff} , the surface gravity, $\log g$, and the metallicity, $[\text{Fe}/\text{H}]$, of 119 stars selected for asteroseismic targets for Kepler. There is one subdwarf in this sample, HIP 92775; all the remaining stars have solar metallicity or are slightly metal-deficient (see Molenda-Żakowicz et al. 2007, 2010; Molenda-Żakowicz, Frasca & Latham 2008; Catanzaro et al. 2010; Frasca et al. 2010.)

In the top panel of Fig. 2, we plot the program stars in the $T_{\text{eff}} - \log g$ diagram constructed with the use of the parameters derived from spectroscopy (dots) and those from the Kepler Input Catalog² KIC (circles) derived from the photometric observations acquired in the Sloan filters. The next panels show the differences between the T_{eff} , $\log g$ and

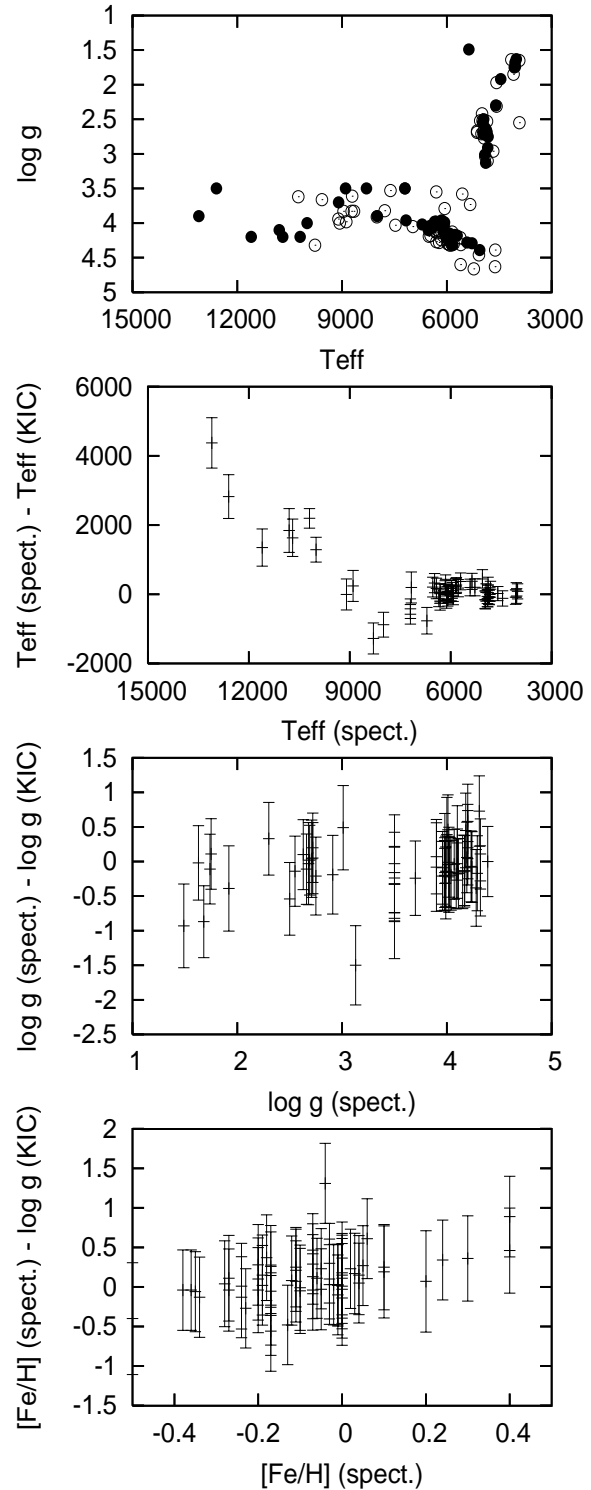


Fig. 2 *Top:* The $T_{\text{eff}} - \log g$ diagram for the program stars plotted with the use of T_{eff} and $\log g$ from the Kepler Input Catalog KIC (circles) and the values derived from spectroscopy (dots). *The next panels from top to bottom:* The differences between T_{eff} , $\log g$ and $[\text{Fe}/\text{H}]$ derived from spectroscopy and those given in the KIC.

² <http://archive.stsci.edu/>

Table 1 The number of the spectrograms acquired for each program star at the Osservatorio Astrofisico di Catania, OAcT, the F. L. Whipple Observatory, FLWO, the Oak Ridge Observatory, ORO, and the Multiple Mirror Telescope, MMT.

KIC	OAcT	FLWO	ORO	MMT	KIC	OAcT	FLWO	ORO	MMT	KIC	OAcT	FLWO	ORO	MMT
2696947	1	1	–	–	6945099	1	–	–	–	10068307	1	–	–	–
2991548	1	–	–	–	6976475	1	1	–	–	10124866	1	49	–	6
3347643	2	–	–	–	7022603	1	–	–	–	10131030	1	–	–	–
3425374	1	1	–	–	7341231	1	–	–	–	10162436	1	–	–	–
3632418	1	–	–	–	7374855	1	–	–	–	10187831	1	–	–	–
3641446	1	–	–	–	7548061	1	–	–	–	10454113	1	–	–	–
3644223	2	–	–	–	7599132	1	–	–	–	10513837	3	1	–	–
3730953	1	–	–	–	7730305	2	–	–	–	10532461	2	–	1	–
3733735	1	–	1	–	7747078	2	–	–	–	10604429	3	–	–	–
3747220	1	–	–	–	7820638	1	–	–	–	10677958	1	–	–	–
3830233	1	–	–	–	7841024	1	–	–	–	10735274	1	–	–	–
3858884	1	–	–	–	7898839	1	–	1	–	10748390	2	4	1	–
3956527	1	4	–	–	7944142	2	–	–	–	10960750	1	–	–	–
4150611	5	–	–	–	7978223	3	–	–	–	11013201	1	–	–	–
4276892	1	–	–	–	7985370	1	–	–	–	11018874	1	–	1	–
4484238	1	–	1	–	8037268	2	2	1	–	11031993	2	33	36	3
4574610	2	–	–	–	8264549	1	1	–	–	11070918	2	2	–	–
4581434	1	–	–	–	8343931	2	–	–	–	11134456	1	–	–	–
4681323	1	–	–	–	8379927	1	3	40	–	11189959	1	–	–	–
4818496	1	–	–	–	8389948	1	–	–	–	11253226	2	–	–	–
4914923	11	5	–	–	8429280	2	–	–	–	11255615	2	–	–	–
5184732	1	–	–	–	8539201	2	–	–	–	11342410	2	–	–	–
5206997	1	–	–	–	8547390	1	–	–	–	11402951	1	–	–	–
5304891	1	–	–	–	8561664	1	–	1	–	11495120	1	–	–	–
5371516	1	–	–	–	8677933	1	–	–	–	11498538	1	–	–	–
5442047	1	–	–	–	8740371	1	–	–	–	11506859	2	–	1	–
5557932	2	–	1	–	8894567	2	2	1	–	11551430	1	–	–	–
5631061	1	–	–	–	8940939	1	–	–	–	11560431	7	–	–	–
5701829	1	–	–	–	9139151	2	–	–	–	11708170	1	–	1	–
5774694	1	1	23	–	9139163	2	–	–	–	11709006	2	–	1	–
5786771	1	–	–	–	9145955	1	–	–	–	11754082	3	–	–	–
6128830	1	–	–	–	9204877	1	2	–	–	11762256	1	–	–	–
6278762	2	6	14	1	9206432	1	–	–	–	11775000	2	–	–	–
6285677	1	–	–	–	9307354	2	2	–	–	12250891	1	–	–	–
6432054	1	–	–	–	9605196	2	–	–	–	12253106	1	–	–	–
6590668	1	–	–	–	9641031	2	12	–	–	12258514	2	–	1	–
6766118	1	–	–	–	9663677	1	–	–	–	12317678	1	–	–	–
6769635	1	–	–	–	9705687	1	–	–	–	12352180	2	4	–	–
6848529	1	–	–	–	9715099	1	–	–	–	12453925	1	–	–	–
6862114	1	–	–	–	10010623	2	–	–	–					

[Fe/H] derived from spectroscopy and those given in the KIC.

As can be seen in the figure, the metallicity derived from spectroscopy and given in the KIC agree satisfactory to within their error bars. We note, however, that the latter are quite large as the uncertainty of [Fe/H] in the KIC is equal to ± 0.5 dex.

The agreement of the values of the surface gravity derived from spectroscopy and given in the KIC is satisfactory for main-sequence stars. For more evolved stars the differences between $\log g$ can be as high as 1.5 dex. Again, the uncertainty of the determination of $\log g$ in the KIC is equal to ± 0.5 dex.

The largest discrepancies occur for the effective temperatures of stars hotter than 7000 K. The origin of these discrepancies is not clear. The uncertainty of T_{eff} in the KIC is ± 200 K in the whole discussed range of T_{eff} .

4 Interstellar reddening

In Molenda-Żakowicz, Jerzykiewicz & Frasca (2009a), we report deriving the interstellar reddening for 29 stars in the Kepler field of view; 19 of these stars are asteroseismic targets for Kepler. We find that, contrary to the information in the KIC, these stars are not reddened while the KIC gives $E(B - V)$ ranging from 0.01 to 0.06 mag for nine of our program stars. We will continue measuring the reddening of the Kepler asteroseismic targets using the data which will be collected for stars selected for photometric observations at several observing sites in 2010. For the details of our observing programme, we refer to Uytterhoeven et al. (2010a).

5 Open Clusters

In 2007, 2008 and 2009 at the OAcT and the Białków Observatory, we observed two open clusters in the Kepler field of view: NGC 6811 and NGC 6866.

The CCD multicolour observations of NGC 6866 acquired at the Białków Observatory in 2007 allowed us to discover 19 variable stars of different types, including three pulsating stars of the δ Sct type, and two, of the γ Dor type (Molenda-Żakowicz et al. 2009b). All these five stars have been included in the list of Kepler asteroseismic targets.

The discovery of γ Dor stars in NGC 6866 allowed us to discuss the properties of open clusters of different age and metallicity which host γ Dor stars (see Molenda-Żakowicz et al. 2009). We showed that there is no relation between these two parameters and the number of γ Dor stars in the clusters.

In 2009, the open cluster NGC 6866 was a subject of a multi-site photometric campaign; in 2010, a similar campaign will be launched for NGC 6811 (see Uytterhoeven et al. 2010b). The aim of these campaigns is to determine the differences in the amplitudes and phases of the pulsating stars measured in the B and V Johnson filters, and to derive the degree of the excited modes of pulsations, l , which will help computing the asteroseismic models of these stars.

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